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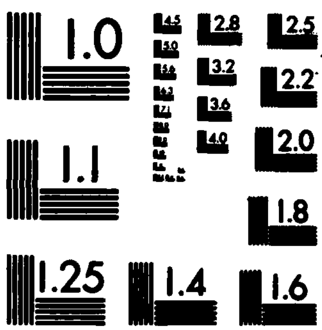

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ELECTRON COLLISION PROCESSES IN MOLECULAR GASES

Final Report

A. V. Phelps

September 30, 1984

U. S. Army Research Office

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electrons, dissociation, hydrogen, oxygen, energy distribution, ionization, anisotropic scattering, excited atom

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The results obtained under this project include a) the experimental determination of coefficients for the dissociation of molecules in electrical discharges, (b) the development of improved techniques for the prediction of the role of electron induced processes such as dissociation and ionization in discharges, and (c) the development of models of high pressure discharges.

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"Transport data for the modeling of electrical breakdown and discharges," in Electrical Breakdown and Discharges, ed. by E.E. Kunhardt and L.H. Leusen (Plenum, New York, 1981), NATO ASI Series 81a, p. 109-132.

"Effect of electrons produced by ionization on electron energy distributions," Phys. Rev. A27, 2858-2867 (1983), with S. Yoshida and L.C. Pitchford.

"Aniosotropic scattering of electrons by N_2 and its effect on electron transport," Phys. Rev. A (to be submitted September 1984), with L.C. Pitchford.

"The role of highly excited atoms in high pressure electrical discharges," Phys. Rev. (in preparation), with P.A. Vicharelli.

"Dissociation of H_2 by low energy electrons," J. Chem. Phys. (in preparation), with M.A. Islam.

PARTICIPATING SCIENTIFIC PERSONNEL:

Dr. A. V. Phelps (principal investigator)
Dr. M. A. Islam (postdoctorate)
Dr. L. C. Pitchford (postdoctorate)
Dr. B. Stumpf (postdoctorate)
Dr. P. A. Vicharelli (postdoctorate)
Mr. J. M. Urbanowitz (undergraduate)

No degrees were earned by participating scientific personnel.

STATEMENT OF PROBLEM:

The objectives of this research were a) to obtain the experimental data and develop the techniques required to predict the role of electron impact induced dissociation of molecules in electrical discharges such as high-power diffuse discharge switches, and b) to develop improved models of transient discharges in high pressure gases.

RESULTS:

The results obtained under this project between January 1, 1981 and ~~June~~ SEPT. 30, 1984 can be conviently divided into a) the experimental determination of coefficients for the dissociation of molecules in electrical discharges, b) the development of improved techniques for the prediction of the role of electron induced processes such as dissociation and ionization in discharges, and c) the development of models of high pressure discharges.

(a) Experimental measurement of molecular dissociation.

We have developed and applied an improved discharge technique for the measurement of the dissociation coefficients for molecules by moderate energy electrons. In order to measure the density of atoms in the same volume as that in which they are produced, we measure the relative atom density and the time constant for loss of atoms using the atomic resonance absorption method. These measurements are made absolute by comparing the absorption by atoms produced by electron impact with the absorption by atoms produced with a known efficiency by argon metastables. The metastable density is determined by measurements of absorption in the near infrared using lines of measured spectral width.

The experimental results obtained with H_2-Ar mixtures have been analyzed to obtain coefficients for electron induced dissociation of the H_2 and for metastable excitation and ionization of the Ar. At the higher E/n the ionization coefficients are in good agreement with predictions of our Boltzmann code. Our metastable excitation coefficients are much lower than expected on the basis of published values for pure Ar, but scale satisfactorily with recent unpublished data by Tachibana. The derived total H_2 dissociation coefficients are consistent with the lower metastable production rates. These results will be used to analyze our data for electron induced dissociation in pure H_2 discharges. Attempts to apply this technique to O_2-Ar discharges in order to obtain dissociation coefficients for O_2 have been unsuccessful thus far because of the difficulties in operating the pulsed discharge in O_2.

(b) Prediction of electron transport and reaction coefficients.

In order to analyze the results of the measurements of the coefficients for dissociation of molecules such as H_2 and O_2 and to use these results to predict the behavior of electrons in gases such as air, one must have reliable techniques available for solution of the Boltzmann equation for electrons. Accordingly, we have been investigating the accuracy of techniques for solution of this equation. Firstly, we examined the effects of including the two electrons produced by ionization on calculated electron energy distributions and transport coefficients. We found that as the electric to gas density ratio E/n was increased it was necessary to use increasingly accurate descriptions of the distribution in energy of the secondary electrons. More recently, we investigated the effects of including anisotropic electron scattering on calculated electron energy distributions and transport coefficients. We find that the effects of an isotropic scattering are small for low E/n provided that the momentum transfer cross section is used for elastic scattering. At E/n above 500 x 10^{-21} V m^2 anisotropic scattering effects become noticeable, but are less important than proper allowance for anisotropy in the electron energy distribution. We have also derived an effective cross section for the resonant rotational excitation of N_2 which is able to reproduce the Russian data on rapid heating of N_2 in electron beam excitedN_2.

(c) Models of high pressure, transient discharges.

The portion of this research carried out under ARO support was concerned with the development of simplified techniques for the modeling of the role of highly excited atoms in high pressure discharges. In particular, we have formulated a simplified model of the rates of ionization and recombination of highly excited atoms which includes the effects of both electron and neutral particle collisions with high excited atoms. The results of this model are in a form appropriate for inclusion in a hydrodynamic model of the time development of constricted discharges. Beginning on January 1, 1983 this research was transferred to AFOSR support.

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